REMARKS

The specification of the subject U.S. patent application, as filed, as constituted by the verified translation of PCT/EP2004/050378, has been cancelled in favor of the concurrently presented Substitute Specification. A suitable Abstract of the Disclosure has been added. These changes and additions do not constitute any new matter.

Original claims 1-81 and Article 34 claims 1-78 have been cancelled. New claims 82-163 have been added. New claims 82-163 are essentially the same, in scope, as the claims which are pending in the PCT application. They have been rewritten more in a form in accordance with U.S. practice and eliminating multiple dependencies.

Entry of this Preliminary Amendment into the file of the subject application on the merits, and prior to the calculation of the filing fee, is respectfully requested.

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<u>DIEDERICHS ET AL.: W1.2099 PCT-US</u>

[Specification]

METHODS FOR THE QUALITATIVE EVALUATION OF A MATERIAL WITH AT LEAST ONE IDENTIFYING CHARACTERISTIC

<u>CROSS-REFERENCE TO RELATED APPLICATIONS</u>

[001] <u>This patent application is the U.S. national phase, under 35 USC 371, of PCT/EP2004/050378, filed March 26, 2004; published as WO 2004/086291 A2 on October 7, 2004, and claiming priority to DE 103 14 071.9, filed March 28, 2003, the disclosures of which are expressly incorporated herein by reference.</u>

<u>FIELD OF THE INVENTION</u>

[002] The <u>present</u> invention <u>is directed</u>[relates] to methods for the qualitative evaluation of a material <u>having</u>[with] at least one identifying characteristic [in accordance with the preambles of claims 1, 2 or 3] <u>A color image is recorded by an electronic image sensor of at least the identifying characteristic</u>.

BACKGROUND OF THE INVENTION

[003] Camera systems are increasingly employed in the printing industry in

connection with various applications, such as, for example, in inspection systems,

in path monitoring systems or in registration measuring systems. These[, wherein

these] systems are typically arranged for use with[at] a printing press or with a

machine which processes material to be imprinted. Moreover, there is a[the]

requirement that these systems should perform their functions "in-line", integrated

into the working process of the printing press or of the machine processing

material to be imprinted. This "in-line" requirement presents[, which represents] a

considerable challenge to the respective camera system because of the large

amount of data provided by the camera system and because of the rapid process

speed of the printing press or of the machine processing the material to be

imprinted. It is difficult, for example, to obtain[for obtaining] a dependable

evaluation, preferably of each identifying characteristic, and even of identifying

characteristics which are difficult to identify by spectral photometry, in spite of the

high transport speed of the material, during the short time available for making

an[the] evaluation in the course of a quality control. Electronic image sensors are often used in such camera systems for recording images. In[, in] particular, these systems often use color cameras with an image sensor consisting of a CCD[CDC] chip, whose light-sensitive pixels provide an output signal, usually, for example, in three separate signal channels, primarily[mostly] for the colors red, green and blue, that are corresponding to the color recorded in the observed range.

[004] A problem that exists with[of] known camera systems in connection with testing colored material, and in particular with testing material imprinted in colors, consists in that the image data provided by the color cameras often do no correspond to the color perception of the human eye. Unprocessed image data received from these color cameras are often insufficient with respect to[regarding] color balance, brightness, contrast and color tone reproduction with respect to[in view of] the color match corresponding to the human color perception. The main reason for this problem, besides the insufficiencies of lenses and illumination devices, is the spectral sensitivity distribution of the color cameras which are employed. If the sensitivity distributions of the color cameras employed does not

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match the sensitivity distribution of the human eye. The[this] result is[s in] that, in

the course of subsequent further processing, for example when the image data is

displayed on a color monitor, the image data provided by the color cameras lead

to a false visual impression. During[, so that during] checking, a reasonable

qualitative evaluation of the imprinted material is [already]hardly possible for this

reason alone.

[005] As a result[Because] of previous production processes, it can occur that the

position of a detection characteristic to be evaluated during the checking process

varies within[in] certain tolerance limits in[within] a defined expected range. For

example, the position of a window thread, such as is used, for example, in

connection with bills or with stamps, in relation to the print image of the bills or

stamps on a printed sheet, can vary because of the properties of the production

process for producing the window thread. Such acceptable[basically tolerable]

position deviations of certain identifying characteristics can generate a malfunction

report in inspection systems, since a print pattern defined as a reference value is

compared sequentially, print position by print position, with the actual printed

image. The result is[, so] that deviations in the position of identifying

characteristics are detected as errors, although they are, in fact, not errors.

[006] For example, a method is known from DE 196 13 082 A2, wherein an[the]

imprinted material, such as, for example, a print sheet imprinted with bills and

provided with a silver thread, hologram or kinegram, is illuminated by an

illuminating device in such a way that the light reflected by the imprinted material

enters a photoelectric sensor. The image taken by the photoelectric sensor can

thereafter be evaluated in an evaluating device, such as, for example, in a

standard computer provided with suitable evaluation software, and can be

checked for printing errors. However, in this case, it is a requirement, for

conducting the evaluation, that an identifying characteristic, whose position varies,

have[has] a sufficiently high reflecting capability, if, for example, [in that]it is

embodied as a shiny silver thread. Accordingly, it is disadvantageous that, after

having been recorded by the use[means] of the photoelectric sensor, that

identifying characteristics, whose image properties do not differ sufficiently

strongly from the image properties of the remaining print image, such as is the

case <u>with,</u> for example, [with]colored window threads, cannot be detected by the

evaluation device with sufficient reliability.

[007] A method for the qualitative evaluation of a material with at least one

identifying characteristic is known from DE 101 32 589 A1<u>. An</u>[, wherein an] image

of the material to be evaluated is recorded by an image sensor<u>. The</u>[and the]

geometric contours and/or the relative arrangement of several identifying

characteristics of this image are evaluated<u>, with</u>[in] respect to each other, in an

evaluation device.

[008] A method for signal evaluation of an electronic image sensor, in connection

with detecting the patterns of image contents of a test body, is known from post-

published DE 102 34 086 A1<u>. A</u>[, in which a] decision regarding the assignment of

the test body to a defined class of test bodies is made.

[009] A measuring arrangement for identifying valuable objects by [means of]

digital image analysis is known from DE 198 02 781 A<u>. A</u>[, wherein a] narrow-band

excitation light source, <u>such as,</u> for example, a tunable laser, illuminates a

selected location area of the object with light within a narrow frequency range<u>.</u>

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Light, which is[, wherein light] reflected by the object, or an emission that is

induced in the object because of its being exposed to radiation, is, for example,

detected by a photometrically calibrated CCD camera having a multitude of pixels,

is digitized and is forwarded to a computer in the form of a data set characterizing

each pixel and is stored in a memory. The[, wherein the] photographically

detected object can also be additionally surveyed, so that information regarding a

geometric arrangement of various objects, their distance from each other or the

depth[dept] of their relief structure, can be added to the data set. The data set

which is prepared from this image detection can be made available, for example

via the internet, and can be used for a comparison of this data set with a data set

prepared for another object, in order to check the other object at the different

location for determining its agreement with the first object, i.e. the original object,

and therefore to check[regarding] its genuineness.

[010] An arrangement for the classification of a pattern, in particular of a bill or a

coin, is known from CH 684 222 A5. A[, wherein a] multi-stage classification

system, which is capable of learning, sequentially performs at least three tests on

a pattern by comparing characteristic vectors with vectorial desired values. A[, wherein a] light source illuminates the pattern and a sensor measures the radiation reflected by the pattern at discrete points in time.

[011] Methods[Customarily, methods] for pattern recognition customarily determine similarities such as, for example, distance measurements on segmented objects, or their calculated global threshold distributions. These methods are based on translation- invariant initial spectra. However, situations often occur in real life, such as by object displacements underneath the recording system, for example, by the existence of different backgrounds during the recordings, or because of aliasing effects, so that in many cases a direct comparison of these initial spectra with stored reference values cannot be performed.

SUMMARY OF THE INVENTION

[012] It is the object of the present invention to provide[create] methods for the qualitative evaluation of a material with at least one identifying characteristic,

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which <u>methods</u> can be employed in the printing industry.

[013] In accordance with the invention, this object is attained by <u>recording a color image of the material having at least one identifying characteristic. A color image is recorded, using an electronic image sensor, of at least the identifying characteristic. At least one first electrical signal, which is correlated with the color image, is made either directly or indirectly by the image sensor. An evaluating device, which is connected with the image sensor, evaluates the electrical signal. A second electrical signal is obtained from a reference image and is stored in a data memory. The first and second signals are compared</u>[means of the characteristics of claims 1, 2 or 3].

[014] The advantages to be obtained by [means of]the <u>present</u> invention lie, in particular, in that a material, <u>and</u> in particular, an imprinted material with at least one identifying characteristic, can also be dependably qualitatively evaluated if the color image taken of the material, <u>and</u> in particular <u>of</u> the identifying characteristics, has optical properties which cannot be sufficiently identified by [means of]spectral photometric methods alone. <u>The</u>[Since the proposed] method

of the present invention does not require that the material to be evaluated

qualitatively have[has] a distinctive reflection capability. It[, it] is thus possible to

define practically any arbitrary, optically detectable property or condition of the

material as its identifying characteristic, so that a clearly expanded application

range of the method results. It is therefore possible to decide [in]what the

identifying characteristics should consist of as a function of the application. The

test is solely dependent on[directed to] there being an optically recognizable

difference [at all]between the identifying characteristic and its surroundings. This

difference is utilized for qualitatively evaluating the material, which evaluation can

also include, for example, the material's[its] identification or a test of its

genuineness.

[015] In particular, the proposed method leads to good results, if it is

also[furthermore] assumed that the position of the identifying characteristic varies

within an expected range which is determined by tolerance limits. Moreover,

with[in] respect to color hues, fullness and brightness, the colors picked up by the

image sensor are arranged sufficiently accurately, in a color range which

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corresponds to the color perception of the human eye, so that the material is

reproduced by a display device, such as, for example, by a color monitor, in the

form of a color image in such true colors, as if the material were inspected directly

by a human eye, so that a dependable qualitative evaluation of the material, and

therefore also of its identifying characteristics, becomes possible by use[means]

of the color image.

[016] The[Here, the] so-called CIELAB color range, which has found wide

application in printing technology, for example, is suitable for use as the color

range. An important characteristic quantity of color deviation in the CIELAB color

range is provided by the color distance Δ[Delta] E between the reference variables

and the actual values of the parameters L, a and b, which characterize the

CIELAB color range. The[, wherein the] parameter L identifies the brightness, a

identifies the red-green value and b identifies the yellow-blue value. These

parameters are also called CIE values. Further characteristic quantities are the

color hue difference Δ[Delta] H and the fullness difference Δ[Delta] C, wherein the

color hue difference Δ[Delta] H, in particular, is important as a characteristic

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quantity in multi-color printing. This is[,] because an off color is subjectively

perceived to be more disturbing than a fullness difference Δ[Delta] C indicating a

brightness difference. Thus, for example, a color distance Δ[Delta] E of a value 1

means a non- visible color difference, a value of 2 means a small difference, a

value of 3 means a recognizable difference,[.] a value of 4 means a clear

difference and, starting at a value of 5, a large difference. The value range of the

CIE values a and b respectively extends from -100 for green or blue to +100 for

red or yellow. The[, the] value range for brightness L extends from 0 (black, total

absorption) to 100 (white, total reflection). The value triplet L = 50, a = 0, b = 0

identifies a neutral medium gray.

[017] Three types of cones (S, M, L) exist in the human eye, which cones absorb

light entering in different spectral ranges. The maximum absorption of the S-type

cones lies in the blue range, namely at 420 nm. The M-type cones maximally

absorb light in the green spectral range, namely at 534 nm. The maximum of the

L-type cones lies at 564 nm in the yellow/red spectral range. Perception by the

use[means] of three cone types is called tri- chromatic perception. Individual[The

individual color perceptions are triggered by stimulation of different strength of the

individual cone types. An identical stimulation of all cone types leads to the

perception of the color white.

[018] Color[However, color] perception phenomena, such as color antagonism

and color constancy, for example, cannot be explained by the tri-chromatic

perception model. Color antagonism means that certain colors can never be seen

in transition, so[i.e.] that no color transition between these colors is possible.

Colors demonstrating color antagonism are called compensation colors or

complementary colors. To be cited among these are the color pairs red/green and

blue/yellow, as well as black/white. In color constancy the different spectral

distribution of the light which, for example, is a function of the weather or of

daylight conditions, is compensated.

[019] Hering developed the compensation color theory in 1920 to explain[for

explaining] these color perception phenomena in a way different from the classic

tri-chromatic color model. The compensation color model assumes that the cones

are arranged in receptive fields, namely in blue/yellow fields and red/green fields.

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In this case, receptive fields are understood to be neurons, as well as the manner

in which the stimulation of the cones is further processed by the neurons. Two

types of receptive fields are substantially responsible for color perception. The

first receptive field obtains its input from the L- and M-cones, the second receptive

field receives its input from the S-cones, together with differently weighted

stimulations of the L- and M-cones. It is assumed that a subtractive color mixture

is performed on the level of the neurons or receptive fields for stimulating the

cones.

[020] The RGB model is the tri-chromatic model for describing additive color

images which is most used in technology. In the RGB model, the color range is

described by the three basic colors red, green and blue. With this model, it is

particularly disadvantageous that the description performed by use[means] of the

RGB model does not correspond with the perception of the human eye, since the

behavior of the human perception in particular, i.e. the perception through the

senses, is not being taken into consideration.

[021] As a rule, electronic image sensors, and in particular CCD chips for color

cameras, have a multitude of, such as, for example, a million or more, [of]light-

sensitive pixels, which are, for example, arranged in a matrix-shape, each of

which pixel, as a rule, provides a first electrical signal corresponding to the colored

light recorded in the observed area and correlated with the color image, which first

electrical signal is split up, for example, in three signal channels which three signal

channels are separated from each other. At[, wherein at] the time of the

observation, each signal channel makes available a portion of the first electrical

signal mainly corresponding to one of the basic colors red, green and blue. Such

a signal is called an RGB signal. Usefully, a spectral sensitivity of each signal

channel ®, G, B)is matched to the spectral sensitivity of the human eye, for

example R = red to 564 nm, G = green to 534 nm and B =[-] blue to 420 nm.

Also, the first electrical signal, in its entirety, is matched with respect to[regarding]

hue, fullness and brightness, to the color perception of the human eye.

Accordingly, a color image recorded by the use[means] of such a color camera is

composed of a multitude of image points.

[022] The method in accordance with the present invention is now distinguished

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in that a second electrical signal is obtained from at least one reference image

and is stored in a data memory. The[, wherein the] second electrical signal

constitutes at least a reference variable for the first electrical signal. By[, that, by

means of] a comparison of the first signal with the second signal, at least the color

image of the identifying characteristic is checked for a color deviation from the

reference image, and/or the identifying characteristic is checked for its affiliation

with a defined class of identifying characteristics, and/or for its affiliation with a

defined geometric contour and/or for a relative arrangement with at least one

further identifying characteristic of the material, each by [means of]a comparison

of the first signal with the second signal for having reached the reference variable

or an agreement therewith. To increase[For increasing] the test dependability, the

material and/or its identifying characteristic is preferably simultaneously always

checked with[in] regard to at least two of the above mentioned criteria. To this

end, at least two of the tests of the color image, and, in particular, the test of the

identifying characteristic for a color deviation from a reference image, and the test

of the identifying characteristic for its affiliation with a defined class of identifying

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characteristics or with a defined geometric contour, or a relative arrangement with

further identifying characteristics of the material preferably take place, at the same

time, in parallel test procedures which run independently of each other. By the

use[means] of the present[proposed] method, an evaluation of imprinted material,

in a running printing process of a printing press, or in a running work process of a

machine, which further processes the imprinted material, is possible for

accomplishing the quality control of this material. This is[,] because of the

resultant test dependability and because of the testing speed with which the

performance of the present method takes place. This material constitutes, in

particular, high-quality printed products which, for example for security reasons,

require[d] very careful testing, and on which great demands are made, [for

example]regarding, for example, the stability of their condition with[in] regard to

print technology, i.e. bills and stamps, in particular.

[023] Testing the color image, for color deviation of the color image from the

reference image, preferably takes place in that the portion of the first signal from

the color image made available in the first signal channel is linked by [means of]a

first calculation prescription with the portion made available in the second signal

channel. An[, wherein an] output signal from a first compensation color channel is

generated so[in] that the portion of the first signal from the color image made

available in the third channel is linked with the portions in the first and the second

signal channel by [means of]a second calculation prescription, by the use[means]

of which an output signal from a second compensation color channel is generated.

The[, and that the] output signals of the compensation color channels are

classified by being compared with reference variables.

[024] Testing the identifying characteristic, regarding its affiliation with a defined

class of identifying characteristics, is preferably performed in that the first electrical

signal made available by the image sensor is converted by the use[means] of at

least one calculation prescription into a translation-invariable signal with at least

one characteristic value. The[, that the] identifying characteristic is weighted with

at least one fuzzy association function. A[, that a] higher-order fuzzy association

function is generated by linking all association functions by use[means] of a

calculation prescription consisting of at least one rule. A[, that a] sympathetic

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value is determined from the higher-order fuzzy association function. The[, that the] sympathetic value is compared with a threshold value. As[and that, as] a function of the result of this comparison, a decision is made regarding the affiliation of the identifying characteristic with a defined class of identifying characteristics.

[025] Testing of the identifying characteristic, regarding a defined geometric contour, and/or a relative arrangement with at least one further identifying characteristic of the material, preferably takes place in that at least one background reference variable and at least one mask reference variable are stored in the memory. The[, wherein the] background reference variable represents at least one property of the material to be evaluated in at least one portion of an area of the vicinity surrounding the identifying characteristic. The[, and wherein the] mask reference variable represents the geometric contour of the identifying characteristic or the relative arrangement of several identifying characteristics among each other. In[, that in] the course of testing the material, a difference value, at least of the expected range, is formed from the first electrical

signal made available by the image sensor and <u>from</u> the background reference

variable<u>. The</u>[, that the] actual position of the identifying characteristic is derived

from <u>a comparison of</u>[comparing] the difference value with the mask reference

variable<u>. For</u>[, and that for] the qualitative evaluation of the material the portion of

the material to be evaluated, which results from the actual position of the

identifying material, is blanked out.

[026] The adaptation of the first electrical signal to the color perception of <u>a</u>[the]

human<u>'</u>s eye takes place in that the RGB signal made available by the image

sensor at every observation time is considered to be a vectorial output signal<u>.</u>

<u>The</u>[, wherein the] coefficients of the RGB signal vector are multiplied with a

correction matrix which is quadratic in particular, so that all portions of the first

electrical signal represented in a signal channel are approximated to the color

perception of the human eye. <u>By</u>[For one, by] multiplying the RGB signal vector

by a correction matrix, a relatively accurate <u>interrelation</u>[intercalation] of all print

colors in a basically arbitrary color range is achieved. Moreover, a matching of the

RGB signal vector<u>,</u> by <u>use</u>[means] of the multiplication with the correction matrix<u>,</u>

can be easily realized by use[means] of data technology, so that an

implementation into an actual system is possible even with large amounts of RGB

signals which are made simultaneously available by a multitude of pixels of the

image sensor.

[027] The coefficients of the correction matrix are, of course, of decisive

importance for the quality of the proposed correction of the RGB signals since,

depending on the selection of these coefficients, the RGB signal vectors are

transformed in different ways. For example, the coefficients of the correction

matrix can consist of empirical values. They are stored in a data memory.

[028] To match[For matching] the coefficients of the correction matrix variably to

different side constraints, such as, for example, regarding the color camera used,

to the illumination conditions, or to the lenses used, an iterative approximation

algorithm is proposed. A reference color chart, such as, for example, an IT8 chart

with 288 color fields, is preset for performing this approximation algorithm. The

different reference colors are represented in the color fields. Moreover, the

assignment of the different reference colors to a suitable color range, for example,

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to the CIELAB color range, is known. From these preset CIELAB values for the

various reference colors of the reference color chart, it is possible, by the

use[means] of known transformations, to calculate corresponding reference

variables for the three signal channels. Thus, a reference color chart is preset as

the input value for the approximation algorithm, and for each reference color as a

vector with a reference variable for each color channel as a desired result of the

conversion. In the course of performing the approximation algorithm for the

determination of the coefficients of the correction matrix, the reference color chart

is recorded by use means of the image sensor of the color camera, and an RGB

signal vector is determined for each color field. The difference between these

RGB signal vectors of the color camera and the vector with the preset reference

variables corresponds to the difference between the color perception of the

human eye and the sensitivity distribution of the color camera.[,]

[029] In order not to have to calibrate the illumination source to a standard light

source, when using respective camera systems, it is possible to perform a further

correction step. In this further correction step, the coefficients of the RGB signal

vectors are converted in such a way that the result corresponds to those RGB

signal vectors which would be obtained when illuminating the observation area by

the use[means] of standard light. The color correction values for use in matching

the RGB signal vectors to different illumination sources and changes can be

advantageously calculated in the following way.

[030] At present, the standard light D50 is still being used in printing technology.

By specifying the illuminant D50, it is possible to adapt Rec. 709 to D50 standard

light by [means of]a conversion so that the non-linear RGB signal vectors behave

as if the object to be tested were illuminated by [means of]D50 illumination. It is

possible, by use[means] of the [proposed]method of the present invention, to

match the RGB signal vectors iteratively to the CIELAB color range without an

actual standard illumination being necessary. This method has the advantage

that, in case of an expected change of the specified standard light, a match can

immediately be provided.

[031] The starting point of the iteration is a correction matrix whose coefficients

have been preset as the initial values. These initial values can either be selected

purely accidentally, or corresponding to defined empirical values. In the first

iteration step, this correction matrix is now multiplied by all of the RGB signal

vectors made available by the image sensor, and the corrected RGB vectors thus

obtained are temporarily stored in a data memory. Subsequently, the coefficients

of the correction matrix are slightly changed, and the multiplication is again

performed. The change of the coefficients of the correction matrix is respectively

only performed if the corrected RGB signal vectors approximate the vectors with

the preset reference variables.

[032] The approximation of the corrected RGB signal vectors to the vectors with

the preset reference variables is weighted for each iteration step in order to be

able to determine by [means of]this weighting, whether the change of the

coefficients of the correction matrix performed made in this iteration step is to be

accepted or discarded. An advantageous weighting method provides, that for

each color field of the reference color chart, the difference value between the

corrected RGB signal vector and the vector with the preset reference values for

this color field is determined and the sum of all these difference values is added.

The change of the correction coefficients of the correction matrix in the actual

iteration step is only accepted if the sum of all difference values in this actual

iteration step has become smaller, in comparison to the sum of all difference

values in the previous iteration step. If[But if] the sum of all difference values has

become greater, because of the change of the coefficients of the correction matrix

in the previous iteration step, the change of the coefficients is discarded. By

use[means] of this summary consideration of the difference values of all reference

colors, it is easily possible that the difference between individual reference colors

is increased during an iteration step. However, as a whole, the minimization of the

difference values is dependably assured over all signal channels.

[033] A further problem in connection with the use of camera systems is the

correct setting of the color balance, i.e. the correct weighting of the various signal

channels with[in] respect to each other. In order to adjust the color balance of the

individual signal channels relative to each other, the coefficients of each RGB

signal vector can [each]be multiplied with a correction factor which is a function of

the signal channel. At the same time, a correction factor is added to each RGB

signal vector. This correction of the three signal channels of each RGB signal

vector corresponds to a linear displacement of the individual coefficients of the

RGB signal vectors.

[034] A particularly good color balance is achieved if the correction vector, and

the correction vectors which are a function of the signal channels, are selected in

such a way that the corrected RGB signal vectors obtained by the application of

the correction by use[means] of the correction vector and of the correction factors

for the two fields with the reference gray values black and white substantially

correspond exactly to the vectors with the preset reference variables of these two

color fields. In other words, this means that the linear displacement of the RGB

signal vectors is selected to be such that corrected results are obtained for the two

reference gray values black and white which correspond to the color perception of

the human eye. Preferably, this linear displacement is applied to all of the RGB

signal vectors, so that brightness and contrast are automatically also corrected

over the entire color spectrum.

[035] When using color cameras, color distortions and a reduction of intensity,

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particularly[in particular] at the edges of the camera images, can occur. These

distortions are generated by the optical devices used, such as, for example, by the

lenses used. A so- called shading correction can be employed to correct[for

correcting] this intensity reduction. To this end, correcting factors, as a function of

the signal channel, are specified for each pixel. By multiplying these pixel-

dependent correction factors with the coefficients of the RGB signal vectors, it is

possible to compensate for the pixel-specific color distortions or for a reduction of

the intensity because of the structural type in the various areas of the image

sensor.

[036] For example, it is possible to detect these pixel- specific, signal channel-

dependent correction factors experimentally in a simple manner. The[in that the]

observed area of the color camera is lined with a homogeneous material, and in

particular with a homogeneous white material, and an RGB signal vector is

determined for each pixel by use[means] of the camera. The[Then that] RGB

signal vector having the highest value coefficients, and which therefore represents

the brightest location in the observed area, is filtered out of these RGB signal

vectors. However, since the observed area has been lined with a homogeneous

colored material, all of the pixels should provide substantially [provide]identical

RGB signal vectors. Therefore, the respective differences are based on color

distortions or on a reduction in intensity as a result of the structural type. To

compensate for this, correction factors are now selected for each signal channel

of each individual pixel, which correction factors see to it that, in the course of

recording the homogeneous colored material, all of the RGB signal vectors

correspond to the RGB signal vector at the brightest location in the observed area.

[037] Color distortions depend, in particular, [depend]greatly on[from] the

illumination conditions in the observed area. To prevent error sources based on a

change of the illumination conditions, the illumination used during the

experimental determination of the pixel-specific, signal channel-dependent

correction factors of the illumination should therefore correspond to the

illumination used during the subsequent employment of the camera system.

[038] In many cases of the application of the method for matching the first

electrical signal to the color perception of the human eye, the corrected RGB

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signal vectors, obtained by the correction of the RGB signal vectors originally

made available by the color camera, are employed for controlling the separate

signal channels of a color monitor. Here, the representation of the colors on the

color monitor also creates the problem that the representational characteristics of

most color monitors do not[no] correspond to the color perception of the human

eye. This is based, in particular, on the fact that the brightness behavior of the

color monitor is, as a rule, [is]not linear, so that[i.e.] the intensity of the light

produced at the color monitor[,] is a non-linear function of the electrical input

signals arriving at the color monitor, in this case of the RGB signal vectors.

This[In other words this] means that, in the case where the RGB signal vectors,

which had been corrected to match the color perception of the human eye, are

merely transmitted to the color monitor and are displayed there, without taking the

non-linearity of the monitor's[its] brightness behavior into consideration, undesired

distortions in the color image can occur on the color monitor. In that case, a

dependable qualitative evaluation of a material represented on the color monitor,

in particular of a material with an identifying characteristic, is then objectively not

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possible.

[039] To prevent such color distortions in connection with their[the]

representation on a color monitor, the coefficients of the corrected RGB signal

vector, which had been used as a basis, can each be raised to a higher power by

a factor γ[gamma]. By [means of]this non-linear conversion of the coefficient of

the corrected RGB signal vector, it is possible to compensate for the non-linearity

of the brightness behavior of most color monitors. It is necessary, for most color

monitors, to select a value in the range between 0.3 and 0.5, and in particular of

approximately 0.45, for the factor γ[gamma].

[040] In the method of[for] testing the color image for a color deviation from the

reference image, the processing of the stimulations, in connection with human

color perception, is simulated. To reproduce[For reproducing] the three cone

types of the human eye, with their differing spectral sensitivity, a signal vector is

made available by each pixel for the color image recorded by the color sensor,[-]

as already mentioned[-], whose coefficients preferably represent three signal

channels that are separated from each other. Each one of the three signal

channels has a characteristic spectral sensitivity. The two receptive fields

representing the second stage of color processing in human vision, are simulated

by an appropriate linkage of the three separate signal channels. The red/green

field of human color perception represents the first compensation color channel in

the technical model. The output signal of the first compensation color channel is

generated by the linkage of the portion of the signal vector in the first signal

channel with the portion of the signal vector in the second signal channel. Linkage

takes place by [means of]a calculation prescription consisting of at least one

arithmetic rule. The blue/yellow field is created in the technical model by the

linkage of the portion of signal vector in the third signal channel with a combination

of the portions of the signal vectors from the first and second signal channel. In

the technical model, the blue/yellow field corresponds to the second

compensation color channel. The output signal of the second compensation color

channel is generated by the above-described linkage. Linkage takes place by the

use[means] of a second calculation prescription consisting of at least one

arithmetic rule. To evaluate[For evaluating] the signal vector of the tested pixel, a

classification of the output signals of the two compensation color channels takes

place in the next step. By [means of]this process, it is determined whether the

signal vector of the tested pixel, and therefore in the end also of the color image,

corresponds to a defined class, by [means of]which determination a good/bad

classification can be made.

[041] For the principle of the method of the present invention, it is of negligible

importance in which spectral range the signal channels of the method operate, as

long as they are signal channels of different spectral sensitivity. It is

advantageous if the signal channels correspond to the three basic colors of the

RGB model, namely red, green and blue, because with this, use is made of a

widely distributed color model. The spectral sensitivity of each signal channel is

advantageously matched to the spectral sensitivity of the cone types in the retina

of the human eye.

[042] It is of secondary importance, in accordance with[for] the principle of the

present invention, in which way the two output signals of the compensation color

channels are generated. One option lies in that an arithmetic rule of the first

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calculation prescription provides a weighted difference formation of the portion of

the signal vector in the second signal channel from the portion of the signal in the

first signal channel, and/or that an arithmetic rule of the second calculation

prescription provides a weighted difference formation of the weighted sum of the

parts of the first and second signal channel from the portion of the third signal

channel.

[043] Preferably, at least one signal, in at least one compensation color channel,

is subjected to a transformation prescription after and/or prior to the linkage, and

in particular is subjected to a non-linear transformation prescription. A

transformation has the particular advantage that the digital character of

electronically generated color images can be taken into consideration. By

use[means] of the transformation prescription, it is also possible to transform a

signal from the color range into a range, in which the stimulation of the cones can

be described. Preferably, the signals in both compensation color channels are

subjected to a transformation.

[044] Since the receptive fields in human vision are characterized by a low pass

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behavior, it is sensible to filter at least one signal in at least one compensation

color channel by the use[means] of a low pass filter. Preferably, the output signal

of every compensation color channel is filtered by [means of]a low pass filter.

[045] Preferably, the method in accordance with the present invention has a

learning mode and a[an] working mode. In particular, an evaluation device, which

is processing the signals from the image sensors, can be switched between these

two operating modes, i.e. between the learning mode and the working mode.

During the learning mode, at least one reference image, such as, for example, the

recording of at least a single printed sheet, is checked pixel by pixel, and the

output signals from the two compensation color channels generated by the

reference image are stored in a data memory as a second electrical signal

constituting a reference variable. In actuality, this means that a signal vector of

the reference image is made available, for example, in three signal channels, that

the portions of the signal vector made available in each signal channel are

matched with[in] respect to perception, and that these portions are thereafter

linked with each other corresponding to the compensation color model. Then the

output signals from each compensation color channel are stored pixel by pixel in

the data memory. In the subsequent working mode, the output signals of the

respective pixel, created by a color image to be tested, [of the respective pixel]are

compared with the corresponding values stored in the data memory in the form of

reference variables, and a classification decision is then made.

[046] In order to take permissible color fluctuations of the color image, as well as

fluctuations of the conditions during the taking of the image into consideration, it is

practical for the values stored in the data memory to be formed by several

reference data sets, so that a permissible tolerance window is fixed in the data

memory for each value, within which permissible tolerance window an output

signal value of a compensation color channel, generated during the image testing,

is permitted to fluctuate. In this case, the reference variable of the output signal of

a compensation color channel can be determined, for example, by arithmetic

average value formation from the individual values, wherein the individual values

result from the reference data sets. For example, the tolerance window can be

determined by the minimum and maximum values of, or by the standard deviation

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from, the output signals generated by the tested reference images of the

compensation color channel of each pixel.

[047] The method for checking the identifying characteristic, regarding its

affiliation with a defined class of identifying characteristics, preferably proceeds

through the following substantial method steps: characteristics formation,

fuzzyfication, interference, de-fuzzyfication and decision regarding a class

affiliation.

[048] During the characteristics formation, the first electrical signal made

available by the image sensor is converted, by the use[means] of at least one

calculation prescription, into a translation-invariant signal within a range of

characteristics. The aim of the characteristics formation is the determination of

those values by the use[means] of which typical signal properties of the color

image are characterized. The typical signal properties of the color image are

represented by so-called characteristics. In this case, the characteristics can be

represented by values within the characteristic range, or by linguistic variables. A

signal is created by [means of]the conversion of the first electrical signal in the

characteristic range, which signal consists of one characteristic value or of several

characteristic values.

[049] The affiliation of a characteristic value with a characteristic is described by

at least one fuzzy affiliation function. This is a soft, or is a[also] fuzzy association

wherein, as a function of the value of the characteristic value, the affiliation of the

characteristic value with the characteristic exists within a standard interval

between 0 and 1. The concept of affiliation leads to a characteristic value no

longer being either wholly affiliated, or not at all affiliated with a characteristic.

Instead,[, but instead] it can take on a fuzzy affiliation which lies between the

Boolean logical values 1 and 0. The above-[just] described step is called

fuzzyfication. Thus, during fuzzyfication, [substantially]a conversion of a hard

characteristic value into one or into several fuzzy affiliations substantially takes

place.

[050] In the course of interference, a higher level affiliation function is generated

by [means of]a calculation prescription consisting at least of one rule, wherein all

affiliation functions are linked together. As a result, a higher order affiliation

function is obtained for each window.

[051] In the course of de-fuzzyfication, a numerical value is determined from the higher order affiliation function formed from the interference, which numerical value is also called a sympathetic value. During the decision regarding the class affiliation, a comparison of the sympathetic value with a previously fixed threshold value takes place, by [means of]which comparison, the affiliation of the window to a specified class is decided. In this case, the threshold value forms a further reference variable which is contained in the second electrical signal.

[052] It is of secondary importance, for the basic progression of the method in accordance with the present invention, of which type the characteristic values in the characteristic range are. For example, in the case of time signals, it is possible to determine their mean value or their variation as the characteristic values. If the requirement is made of[on] the method for checking the identifying characteristic, for its affiliation to a defined class of identifying characteristics, that it is to process the color images free of errors, regardless of the respectively prevailing signal intensity, and if furthermore small, but permissible fluctuations in

the color image are not to result in interferences, it is sensible to perform the

conversion of the first electrical signal from the two-dimensional local range by the

use[means] of a two-dimensional spectral transformation. Examples of a suitable

spectral transformation are respectively two-dimensional Fourier, Walsh,

Hadamard or circular transformations. Translation-invariable characteristic values

are obtained by the use[means] of the two- dimensional spectral transformation.

The value of the spectral coefficients, obtained by use[means] of a spectral

transformation, is preferably used as characteristic value.

[053] The affiliation functions are preferably unimodal potential functions. The

higher order affiliation function is preferably a multi-modal potential function.

[054] It is advantageous to parametrize at least one affiliation function. If the

affiliation function has positive and negative slopes, it is advantageous if the

parameters of the positive and negative slopes can be separately determined. A

better matching of the parameters with the data sets to be examined is assured by

[means of]this paramiterization.

[055] In accordance with a particularly preferred [exemplary]embodiment of the

present invention, the method is again divided into two different modes of

operation, namely into a learning mode and into a working mode. If the affiliation

functions are parametrized, it is possible, in the learning mode, to determine the

parameters of the affiliation function from measured data sets. In the learning

mode, the parameters of the affiliation functions are matched with so-called

reference images, so that[i.e.] in the learning mode, an affiliation of the

characteristic values resulting from the reference images with the corresponding

characteristics is derived by the use[means] of the affiliation function and its

parameters. In the subsequent working mode, the characteristic values resulting

from the subsequently measured data sets are weighted with the affiliation

functions whose parameters had been determined in the learning mode, by the

use[means] of which, an affiliation of the characteristic values of the now

measured data sets with the corresponding characteristics is established. Thus,

the parameters of the affiliation functions are determined by the use[means] of

measured reference data sets because of the division of the method into a

learning mode and a working mode. The data sets to be tested are weighted in

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the working mode by the affiliation functions which were determined in the

learning mode and are evaluated.

[056] Furthermore, a rule by [means of]which the affiliation functions are linked

with each other preferably is a conjunctive rule within the meaning of an IF..THEN

linkage.

[057] The generation of the higher order fuzzy affiliation functions is preferably

divided into the following partial steps: premise evaluation, activation and

aggregation. In the premise evaluation, an affiliation value is determined for each

IF portion of a rule[rue], and during activation, an affiliation function is determined

for each If...THEN rule. Thereafter, during aggregation, the higher order affiliation

function is generated by overlaying all of the affiliation functions created during

activation.

[058] It is advantageous to perform the sympathetic value determination in

accordance with a focus and/or a maximum method.

[059] Checking the identifying characteristic for a defined geometric contour

and/or for a relative arrangement, with[in] respect to at least one further identifying

characteristic of the material, is based on the basic idea of additionally letting

known information regarding this identifying characteristic enter into the

evaluation in the course of evaluating a positionally variable identifying

characteristic, for which the optical properties, for example the reflection

capability, does not suffice for a sufficiently dependable identification. A premise

in this case is that the positionally variable identifying characteristic, <u>such as,</u> for

example, a colored window thread, differs in its optical properties, for example

<u>in</u>[by] its gray value, at least in partial areas, sufficiently from the remaining

material to be inspected, <u>such as,</u> for example, the print image surrounding the

identifying characteristic, <u>so</u> that there is at least no complete correspondence

between the identifying characteristic and the print image. Thus, for determining

the position of the positionally variable identifying characteristic, additional

information regarding the contour, <u>which is</u> known per se, of the identifying

characteristic or the relative arrangement of several identifying characteristics

contained in the print image are evaluated. This additional information is then

stored in a mask reference <u>which is</u> stored in the data memory in regard to every

material to be evaluated, which represents the geometric data in a suitable form.

[060] Furthermore, a background reference variable has been stored as a

reference in the data memory, which <u>background reference variable</u> represents

the optical properties of the print image in at least a part of an area surrounding

the identifying characteristic. The optical properties of the background reference

variable must differ, at least slightly, from the optical properties of the identifying

characteristic to be detected. In the course of testing the material, a differential

value, which represents a differential image at least of the expected area, is then

formed from the actual first electrical signal made available by the image sensor

and the background reference variable.

[061] Substantially all <u>of the</u> characteristics of the print image, which correspond

in their optical properties to the background reference <u>variable</u>[variably], are

blanked out of the differential image by <u>the use</u>[means] of the difference

formation. Only positionally variable areas of the identifying characteristic and

also <u>of</u> other elements, such as printing errors or deviations of the edges, are

represented in the differential image because of their deviation from the

background reference value, wherein the areas of the positionally variable

identifying characteristic have particularly high amplitudes.

[062] As soon as the differential values are available, these[the] differential

values are compared with the mask reference variables of the mask reference,

and[an] a conclusion regarding the actual position of the identifying characteristic

is drawn from the result of the comparison. This method step is based on the

reflection that the differential image is substantially determined by the

representation of the positionally variable identifying characteristic, so that a

conclusion regarding the actual position of the positionally variable identifying

characteristic can be drawn from the considerable overlapping of the mask

reference and the differential image. If no sufficient overlap between mask

reference variables and differential values can be determined, because of other

error effects, this is harmless, since this merely leads to an error indication in the

course of the print image check, for example, and to the removal of the respective

printed sheet.

[063] Preferably, the areas of the print image, resulting from the actual position of

the identifying characteristic, are blanked out during the subsequent qualitative

evaluation of the material, so that interferences with the checking of the print

image, because of the positionally variable arrangement of the identifying

characteristic, are excluded.

[064] The detection of the positionally variable identifying characteristic can be

improved during the performance of this method in that a threshold for binary

formation is stored in the data memory. After the differential image has been[was]

formed from the first electrical signal and the background reference variable, all

image data, whose values lie below the threshold for binary formation, can be

filtered out of the differential image. This means that only those image points

remain in the differential image which differ with considerable significance from

the remaining print image, so that the mostly other deviations, for example printing

errors or edge deviations, can be blanked out of the differential image.

[065] The procedure, in the course of determining the position of the positionally

variable identifying characteristic in the actual print image, can be such that the

mask reference is shifted until a maximum overlap between the mask reference

and the differential image results. Various mathematical evaluation methods can

be employed for this, for evaluating the overlap between the mask reference and

the differential image and for finding the appropriate overlap maximum. It is, of

course, possible to provide the evaluation of the overlap by a visual check

performed by sufficiently trained checking personnel which, however, because of

the high costs of personnel and the low processing speed, is not sufficiently

economical in most cases. Therefore, the calculation of the overlap between the

differential image and the mask reference should take place by using suitable

mathematical operations by the use[means] of methods of electronic data

processing, if possible.

[066] A possibility for evaluating the overlap between the mask reference and the

differential image consists in the calculation of foci in accordance with the optical

distribution of the image points in the differential image, and in comparing these

foci with the focus of the mask reference. Maximum overlap results when the sum

of the focus differences between the mask reference and the differential image is

minimized.

[067] A prerequisite for performing this method for testing the identifying

characteristic for a defined geometric contour and/or <u>for testing</u> a relative

arrangement<u>, with</u>[in] respect to at least one further identifying characteristic of the

material, is the storage of a suitable background reference variable in the data

memory. In principle, the background reference variable can be simply preset as

a method parameter, <u>such as,</u> for example<u>, a parameter</u> based on one, or <u>on</u>

several empirical values. However, it is advantageous if the background

reference variable is specifically fixed in a learning mode as a function of the

respective print image of the material to be tested. Two alternatives of this will be

<u>discussed</u>[shown] in what follows.

[068] In accordance with <u>a</u>[the] first alternative for determining the background

reference variable, reference material, which does not contain the positionally

variable identifying characteristic, is used in the learning mode. For example,

printed sheets imprinted with bills or stamps can be used for this, which <u>printed</u>

<u>sheets</u> do not have the window thread. By evaluating this reference material

without the identifying characteristic it is possible to derive [at]the background

reference variable.

[069] If reference material, without an identifying characteristic, is not available,

the learning mode can also be performed using[with] reference material containing

the positionally variable identifying characteristic. If, in the course of evaluating

the print image of the reference material, the positionally variable identifying

characteristics appear bright, in comparison with the surrounding area, a threshold

value, corresponding to the values of the darkest image points of the identifying

characteristic, is selected as the background reference variable. In the course of

[the]subsequent testing of the material, it is then assumed, based on the

threshold value, that, at least in the expected area, all image points which are

darker than the background reference variable are not a part of the positionally

variable identifying characteristic. But, if in comparison with the surrounding area,

the identifying characteristic appears dark, a threshold value is selected as the

background reference variable whose value corresponds to the brightest image

points of the identifying characteristic.

[070] To the extent that it is required on the basis of the optical properties of the

print image, it is, of course, possible to define different background reference

variables for different areas of the material, so that the positionally variable

identifying characteristic is pictured with sufficient significance in the differential

image.

BRIEF DESCRIPTION OF THE DRAWINGS

[071] Preferred[Exemplary] embodiments of the present invention are

represented in the drawings and will be described in greater detail in what follows.

[072] Shown are in:

Fig. 1, a block diagram with functional units which are relevant to the

method in accordance with the present invention, in

Fig. 2, method steps in the course of performing the method for testing the

color image for a color deviation from a reference image in accordance with the

present invention, in

Fig. 3, a schematic representation of the method for testing for color

deviations in the recorded color image with a compensation color model, in

Fig. 4, a flow chart of the learning and working mode, as well as of the

classification, in

Fig. 5, a flow diagram of the method for testing the identifying characteristic

for its affiliation with a defined class of identifying characteristics, in

Fig. 6, a top plan view of a schematically represented differential image[in

a view from above], in

Fig. 7, a differential image in accordance with Fig. 6 following the

performance of a binary formation, in

Fig. 8, a[the] mask reference for determining the position of the positionally

variable identifying characteristic in the differential image in accordance with Fig.

7, in

Fig. 9, the overlap between the differential image in accordance with Fig. 7

and the mask reference in accordance with Fig. 8, in

Fig. 10, a second mask reference in a schematically represented side

elevation[lateral plan] view, and in

Fig. 11, a second differential image in a schematically represented side

elevation[lateral plan] view.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[073] A block diagram with the functional units relevant for the performance of

a[the] method for the qualitative evaluation of an imprinted material 19 with at

least one identifying characteristic, in accordance with the present invention, is

shown in Fig. 1. A color camera 01, which, for example, has been attached fixed

in place, either in, or at a printing press, is positioned so that with its image sensor

02 it can record color images of a[the] material 19 to be evaluated. The material

19[, which] is moved past the color camera 01, preferably in the course of a[the]

running print process, which color camera 01 is connected to an evaluating

device 03. The image data recorded by the color camera 01 and evaluated in the

evaluating device 03 can be represented, if required, on a color monitor 04. The[,

wherein the] color monitor 04 can be arranged in or at a control console, which is

part of the printing press. The testing methods which, in accordance with the

present invention, are used for the qualitative evaluation of the imprinted material

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19, are represented in connection with the evaluating device 03 in, for example,

[in] three parallel signal paths. The[, wherein the] testing processes in the

respective signals paths preferably take place [preferably]in the same evaluating

device independently of each other. The tests preferably occur at least

approximately at the same time. Typically,[, i.e.] the test processes at least start

at the same time. The test process can start after the evaluating device 03, which

operates in at least two modes of operation, has changed from its learning mode

48 into its working mode 49, as depicted in Fig. 04. One[Respectively one] signal

path relates to a first functional unit 06 for testing at least the color image of the

identifying characteristic for a color deviation from the reference image. A second

signal path relates to[,] a second functional unit 07 for testing the identifying

characteristic for its affiliation with a defined class of identifying characteristics. A

third signal path relates to[, and] a third functional unit 08 for testing the

identifying characteristic for a defined geometric contour or for an arrangement

relative to at least one further identifying characteristic of the material 19. Each[,

wherein each] test includes a comparison, performed at a comparison location

11, 12, 13, [14,]of the first signal 09, which has been made available by the

image sensor 02 of the color camera 01 and which has been suitably processed,

with a [respectively]suitably fixed reference variable 16, 17, 18, respectively.

The[wherein the] reference variables 16, 17, 18 are stored in a data memory 14,

which is part of the evaluating device 03. The respective test results present in

the individual signal paths are again reported to the evaluating device 03 for the

purpose of being stored there. The functional units, which are relevant to the

method for the qualitative evaluation of an imprinted material 19 with at least one

identifying characteristic, can also be implemented in a machine which is

processing the material 19. This[, wherein this] machine can preferably be

arranged downstream of, but can also be located upstream of, for example a

printing press, preferably a sheet-fed printing press, and in particular a sheet- fed

rotary printing press. The material 19, such as[i.e.] a printed sheet 19 having, for

example, several identifying characteristics, is imprinted in a printing press at a

speed of, for example, 18,000 sheets per hour and/or is subsequently further

processed in the machine processing these printed sheets 19 at this speed. In

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the situation[case] where the material 19 being evaluated is embodied as a web

19 of material, the printing speed or the further processing speed of the web 19

can be 15 m/s, for example. Although the testing processes for evaluating the

quality of the material 19 to be processed by the printing press or by the machine

are calculation-intensive, and the movement speed of the material 19 is high, a

dependable evaluation is achieved by the use[means] of the [proposed]method

in accordance with the present invention. Since the functional units, which are

relevant to the method for the qualitative evaluation of an imprinted material 19

with at least one identifying characteristic, are arranged in or at the printing press

or the machine processing the material 19, the location for making the reference

signal available and the location of the test are identical. The color image and its

reference image can be recorded by the same functional units, and in particular

can be recorded by the same color camera 01, in the same location, and can be

evaluated in the same evaluating device 03.

[074] The following method steps are performed for the qualitative evaluation of

the imprinted material 19 and will now be explained by way of example by

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referring to[means of] Figs. 2 to 11.

[075] A color image of a material 19, which has been imprinted in color and

which is arranged in an[the] observation area 21, as seen in Fig. 2, is recorded by

[means of]the color camera 01. The color camera 01 has an image sensor 02,

which is preferably embodied as a CCD chip 02, and which converts the image

information recorded in the observation area 21 into electronic image data, which

electronic image data form a first electrical signal 09 that is made available by the

color camera 01, or by its image sensor 02. In the course of this conversion, a

signal vector 22 is generated by each one of the light-sensitive pixels of the CCD

chip 02. The[Corresponding to the number of pixels of the CCD chip 02, the]

color camera 01 makes available a [corresponding]number of signal vectors 22

corresponding to the number of pixels of the CCD chip, and identified by [means

of]a counting index, to the evaluating device 03 for further processing.

[076] Preferably, each signal vector 22 has three coefficients R, G and B. The

coefficients R, G and B correspond to the color values of the three signal

channels red, green and blue. The[, wherein the] vectorially first electrical signal

09 emitted by a pixel is correlated with the recorded color of the imprinted

material 19 at the corresponding position in the observation area 21.

[077] The signal vectors 22, whose counting indices are[index is] used for

describing the arrangement of the respective pixels on the CCD chip 02,

constitute raw data for a first correction module 23 for matching the color balance,

the brightness and the contrast. For this purpose, each coefficient R, G, B of the

signal vector 22 is multiplied by a signal-dependent correction factor K_1, K_2, K_3.

Moreover, to the resulting vector is added a correction vector 24 with the fixed

value coefficients a_1, a_2 and a_3. First corrected signal vectors 26 are created by

this arithmetic operation, which arithmetic operation improves[improve] the color

balance, the brightness and the contrast of the image data. This goal is achieved

because[in that] the signal channel-dependent correction factors K_1, K_2, K_3, as

well as the coefficients a_1, a_2 and a_3 of the correction vector 24 have been

selected in such a way that, in the course of recording the reference gray values

black and white, the signal vectors 22 generated by the color camera 01 are

[here]transformed in such a way that the received corrected signal vectors 26

correspond to those reference variables which result as[as result in] the vectors

from the conversion of the known CIELAB color values.

[078] Thereafter, the first corrected signal vectors 26 are provided to a second

correction module 27. In the second correction module 27, each first corrected

signal vector 26 is multiplied by a quadratic i x i correction matrix 28, wherein i

corresponds to the number of coefficients of the corrected signal vector 26,

wherein in this case i = 3. The second corrected signal vectors 29 result from this

multiplication. The coefficients K_4 to K_{12} of the quadratic correction matrix 28 had

previously been determined in a suitable iteration process in such a way that the

image information contained in the first corrected signal vectors 26 is[are] brought

closer to the color perception of the human eye.

[079] Subsequently, the second corrected signal vectors 29 are forwarded to a

third correction module 31. In the third correction module 31, signal channel-

dependent correction factors relating to each pixel have been stored in a data

memory 14 which, for accommodating the intensity values which depend from the

position of the respective pixels, are multiplied with the coefficients R, G and B.

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As a result, the second corrected signal vectors 29 of the first pixel are multiplied

by the correction factors K_{13}, K_{14} and K_{15} in order to calculate a third corrected

signal vector 32 for the first pixel. Preferably, this correction of the second

corrected signal vectors 29 is performed for all of the pixels of the image sensor

02.

[080]   The third corrected signal vectors 32 are then passed on to a fourth

correction module 33. In the fourth correction module 33, the coefficients R, G. B

of the third corrected signal vectors 32 are raised to a higher power by a factor

γ[gamma] and the fourth corrected signal vectors 34 are calculated from this. By

raising the third corrected signal vectors 32[it] by the factor γ[gamma], the non-

linear brightness transfer function of a color monitor 04 is taken into

consideration, to which the fourth corrected signal vectors 34 are transmitted for

display.

[081] As previously mentioned, the recording of the image signal by an image

sensor 02 takes place in signal channels R, G, B which are separated from each

other. In the present preferred[exemplary] embodiment, the three signal channels

R, G, B are the three signal channels red R, green G and blue B. Each one of the

signal channels R, G, B has an adjustable spectral sensitivity. This has the

advantage that the spectral sensitivity of each signal channel R, G, B can be

adapted to the spectral sensitivity of the respective cone of the retina of the

human eye.

[082] In the course of <u>utilizing</u> the method for checking the color image for a

color deviation from a reference image, the spectral contents of an image is

analyzed pixel by pixel. <u>To model</u>[For modeling] the two receptive fields

red/green and blue/yellow of the human eye, in accordance with Fig. 3 in this

method the image sensor signals of the signal channels R, G, B are linked with

each other[in this method]. Prior to the actual linkage by <u>the use</u>[means] of the

calculation prescriptions 36, 37, each image sensor signal is subjected to a non-

linear transformation 41 in the compensation color channels 38, 39. <u>Because</u>[By

means] of this, the digital character of the electronically created recordings is

taken into consideration. Each signal is subsequently weighted with a coefficient

K_i 42 (i = 1...4). It is achieved by this <u>process</u> that a mere intensity change of the

initial image does not make a contribution to one of the output signals 43, 44 of

the compensation color channels 38, 39. The generation of the output signals 43,

44 of the compensation color channels 38, 39 takes place analogously to the

generation of the signals of the receptive fields in the human retina. This means

that a linkage of the signal channels R, B, G, by use[means] of the calculation

prescriptions 36, 37, is performed in a manner corresponding to the linkage of the

cones of the human retina. For forming[creating] the output signal 43 of the

red/green compensation color channel 38, the image sensor signals of the red

signal channel R and the green signal channel G are linked together by the

use[means] of the first calculation prescription 36. For generating the output

signal 44 of the blue/yellow compensation color channel 39, in the present

preferred[exemplary] embodiment, the image sensor signal of the blue signal

channel B is linked with the minimum 46 of the image sensor signals of the red

signal channel R and the green signal channel G by use[means] of the calculation

prescription 37. The receptive fields of the human retina are distinguished by a

low pass behavior. Accordingly, in the present preferred[exemplary] embodiment,

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the signals obtained by linkage are subjected to low pass filtering 47, for example

by the use[means] of a Gauss low pass filter.

[083] Fig. 4 shows the actual testing of the imprinted material 19, which takes

place in two stages, namely in a learning mode 48 and in a subsequent working

mode 49. The aim of the learning mode 48 is the generation, pixel by pixel, of

reference variables for use as reference data values, which reference data values

are compared in the subsequent working mode 49 with the output signals 43, 44

of the compensation color channels 38, 39 of the corresponding pixels. In the

learning mode 48, the image contents of a reference image 52, or of several

reference images 52, are analyzed in that the image contents of each pixel are

introduced into three signal channels R, G, B, and a subsequent matching, in

accordance with the perception of the image signals of each signal channel R, G,

B, is performed. Thereafter[, and thereafter] further processing of the image

sensor signals is performed, in accordance with the previously described

compensation color method. The output signals 43, 44 of the compensation color

channels 38, 39, which are obtained for each pixel, are then stored in a data

memory 14. In order to also take permissible fluctuations of the reference images

52 into consideration, it is useful if several reference images 52 are considered in

the learning mode 48. It is possible, because[by means] of this, for the stored

reference variables of each pixel to have a permissible fluctuation tolerance. The

fluctuation tolerance can be fixed either by minimum/maximum values or by the

standard deviation from the received data of the image contents of the reference

images 52 of each pixel.

[084] Then, in the working mode 49, a pixel by pixel comparison of the output

values 43, 44 of the compensation color channels 38, 39 of an inspection image

53, with the reference variables from the data memory 14, takes place. This

comparison can be performed by the use[means] of a linear or of a non- linear

classification device 54, and in particular by the use[means] of threshold value

classification devices, Euclidic distance classification devices, Bayes classification

devices, fuzzy classification devices, or artificial neuronal networks. A good/bad

decision [takes]subsequently takes place.

[085] Fig. 5 shows a flow diagram of the signal evaluation, in the method for

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checking the identifying characteristic for its association with a defined class of

identifying characteristics, in accordance with the present invention.

[086] First, a grid of M x N windows 56 is placed over the entire color image to

be checked, wherein M, N > 1. Each window 56 advantageously consists of m x

n pixels, with m, n > 1. A square window 56 of N x N windows 56 is preferably

selected, wherein each window 56 consists of n x n pixels. In the testing process,

the signal of each window 56 is checked separately.

[087] The two-dimensional color image of the local range is transformed, by

use[means] of one or of several two-dimensional spectral transformations 58, into

a two-dimensional image in the frequency range. The obtained spectrum is

called a frequency spectrum. Since, in the present preferred[exemplary]

embodiment, this is a discrete spectrum, the frequency spectrum is also discrete.

The frequency spectrum is constituted by the spectral coefficients 59, which are[-]

also called spectral values 59[-].

[088] The sum formation 61 of the spectral values 59 takes place in the next

method step. The sum of the spectral values 59 is called a spectral amplitude

-63-

value 62. In the present preferred[exemplary] embodiment, the spectral

amplitude values 62 constitute the characteristics values 62, i.e. they are identical

to the characteristics values 62.

[089] The characteristics selection 63 follows as a further method step. It is the

goal of the characteristics selection 63 to select those characteristics 64 which

are characteristic of the image content of the color image to be checked.

Characteristic spectral amplitude values 62, which define the characteristic 64 by

their position in the frequency range and by their amplitude, as well as linguistic

variables, such as "gray", "black" or "white", for example, are possible as

characteristics 64.

[090] In the [now]following method step, the fuzzyfication 66, the association of

each spectral amplitude value 62 to a characteristic 64 is determined by a soft or

by fuzzy association function 67. In other words,[, i.e.] weighting is performed.

[091] If, in a learning mode, the association functions 67 are to be matched to

reference variables, which are stored in the form of reference data sets, it is

useful for the association function 67 to be configured[designed] as parametrized

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monomodal, or as[i.e.] one-dimensional potential functions, in which the

parameters of the positive and negative slopes can be separately matched to the

reference variables to be tested. In the working mode, following the learning

mode, the data sets of the image contents, from which the characteristics values

62 of the color images to be checked result, are weighted with the respective

association functions 67, whose parameters had been determined in the previous

learning mode. This means that for each characteristic 64 a sort of SHOULD BE

- IS comparison takes place between a reference data set, expressed in the

parameters of the association functions 67, and the data set of the color image to

be checked. A soft or a fuzzy association is produced between the respective

characteristics value 62 and the characteristic 64 by the association functions 67.

[092] In the next method step, the interference 68, a substantial conjunctive

linkage 69, [-]also called an aggregation 69, [-]of all of the association functions

67 of the characteristics 64 takes place, by the use[means] of which, a higher

order association function 71 is created.

[093] The next method step, defuzzyfication 72, determines a concrete

association value 73, or a sympathetic value 73, from the higher order association

function 71. In the course of the classification 74, this sympathetic value 73 is

compared with a previously set threshold value 76, so that a classification

statement can be made. The threshold value 76 is set either manually or

automatically. Setting of the threshold value 76 also takes place in the learning

mode.

[094] The method for checking the identifying characteristic, for a defined

geometric contour and/or for a relative association with at least one further

identifying characteristic of the material, substantially takes place during the

following steps.

[095] In accordance with Fig. 6, a differential image 77 had been formed, in the

course of printing[printed] sheets, which are, for example, imprinted with bills 19,

wherein only a portion of the differential image 77, in the area of a bill 19, is

represented in Fig. 8. It can be seen, as depicted in Fig. 6, that the normal print

image of the bill 19 has been blanked out of the differential image 77. Only[and

only] those areas of the print image, which significantly differ from the background

reference value, are represented as dark fields in the differential image 77. In a

strip-shaped expected range 78, which is indicated by dashed lines, the position

of, for example, an identifying characteristic 79 placed into the printed sheet can

vary, which identifying characteristic can be, in particular, an incorporated window

thread 79 which, in accordance with its perforations, is shown in five dark fields

79.

[096] Besides the five dark fields 79 which can be seen in the representation of

the window thread 79, [still]further perforation characteristics are formed in the

differential image 77 as irrelevant dark fields 81 which had been created by print

errors 81, for example.

[097] Fig. 7 shows the differential image 77 following a suitable binary formation,

by the use[means] of which, the irrelevant dark fields 81 were filtered out. As a

result, only the dark fields 79 stemming from the window thread 79 stand out

significantly in the differential image 77.

[098] Fig. 8 represents a mask reference 82 in its geometric shape. The data for

the width 83 and the length 84 of the window thread perforations 79 have been

stored in the mask reference 82. Furthermore, values of the distance 86 between

the window thread perforations 79, and the number of window thread perforations

79 per bill 19, are stored in the mask reference 82.

[099] As is schematically indicated in Fig. 9, during the evaluation the mask

reference 82 is shifted, by the use[means] of technical data operations, in relation

to the differential image 77, until a maximum overlap between the mask reference

82 and the dark fields 79 in the differential image 77 results. Once this maximum

overlap has been achieved, it is possible to draw conclusions regarding the actual

position of the window thread 79 in the print image from the distances 87, 88

which, for example, result from the actual positions in the X and Y directions of

the mask reference 82, in relation to the edges of the bill 19, so that during a

subsequent check of the print image, the areas of the window thread perforations

79 can be blanked out.

[100]   Fig. 10 shows a second mask reference 89, which represents dark fields

91 corresponding to eight window thread perforations 91 in the course of the

check of a bill 19 on a concavely curved support surface.

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[101] Fig. 11 schematically represents a differential image 92, in which the

window thread perforations 91 are shown in dark fields 93, such as, for example,

in window threads 93. In this case, the dark field 94 was caused by a print error

94 and not by a window thread perforation 91. Furthermore, a window thread

perforation 91 in the center is not pictured because of the insufficient color

difference between the background and the window thread 93.

[102] To simplify[For simplifying] the comparison between the mask reference 89

and the differential image 92 for position finding, the mask reference 89 is

projected onto a projection line 96, and the light-dark distribution resulting from

this projection is compared with the light-dark distribution resulting from the

projection of the reference image 92 onto a projection line 97. By the use[means]

of this one-dimensional comparison of the light-dark distribution it is possible to

determine the position of the window thread 93 in one direction.

[103] While preferred embodiments of methods for the qualitative evaluation of a

material with at least one identifying characteristic, in accordance with the present

invention, have been set forth fully and completely hereinabove, it will be

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apparent to one of skill in the art that various changes in, for example, the types

of press used to print the material to be evaluated, the specific computer used,

and the like could be made without departing from the true spirit and scope of the

present invention which is accordingly to be limited only by the appended claims.

WHAT IS CLAIMED IS:

[List of Reference Symbols]

[01   Color camera

02   Image sensor, CCD chip

03   Evaluating device

04   Color monitor

05   -

06   Functional unit

07   Functional unit

08   Functional unit

09   Signal, electric, first

10   -

11   Comparison location

12   Comparison location

13   Comparison location

14   Data memory

15   -

16   Reference variable

17   Reference variable

18   Reference variable

19   Material, bill, stamp, printed sheet, web of material

20   -

21   Observation area

22   Signal vector

23   Correction module, first

24   Correction vector

25   -

26   Signal vector, first, corrected

27   Correction module, second]

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[28 Correction matrix

29 Signal vector, second, corrected

30 -

31 Correction module, third

32 Signal vector, third, corrected

33 Correction module, fourth

34 Signal vector, fourth, corrected

35 -

36 Calculation prescription

37 Calculation prescription

38 Compensation color channel

39 Compensation color channel

40 -

41 Transformation

42 Coefficient K_i (i = 1 ... 4)

43 Output signal (38)

44 Output signal (39)

45 -

46 Minimum

47 Low pass filtering

48 Learning mode

49 Working mode

50 -

51 -

52 Reference image

53 Inspection image

54 Classification device

55 -

56 Window, image window

57 -

58 Spectral transformation

59 Spectral coefficient, spectral value]

[60   - .

61   Sum formation

62   Spectral amplitude value, characteristics value

63   Characteristics selection

64   Characteristic

65   -

66   Fuzzyfication

67   Association function

68   Interference

69   Conjunctive linkage, aggregation, conjunctive
      calculation prescription

70   -

71   Higher order association function

72   Defuzzyfication

73   Association value, sympathetic value

74   Classification

75   -

76   Threshold value

77   Differential image

78   Expected range

79   Dark field, window thread, recognition
      characteristic, window thread perforation

80   -

81   Dark field, print error

82   Mask reference

83   Width

84   Length

85   -

86   Distance

87   Distance

88   Distance

89   Mask reference, second]

[90 | -
91 | Window thread perforation, dark field
92 | Differential image
93 | Dark field, window thread
94 | Dark field, print error
95 | -
96 | Projection line
97 | Projection line

RGB   Coefficient, signal channel
K_1, K_2, K_3 Correction factor
K_4 to K_{12} Coefficient
K_{13}, K_{14}, K_{15} Correction factor
a_1, a_2, a_3 Fixed value coefficient
gamma   Higher power factor]